

1 **INTEGRATED PROTOCOL FOR DIAGNOSIS, TREATMENT, AND**
2 **PREVENTION OF BONE MASS DEGRADATION**

3
4 **Field of the Invention:**

5 The present invention relates generally to the treatment
6 of bone diseases and, more specifically, to methods and systems
7 for diagnosis, treatment, and prevention of ailments related to
8 the loss of bone mass.

9
10 **Background:**

11 Bone mass deterioration is a widespread medical condition,
12 appearing with particular frequency in the elderly and in
13 women. The gradual depletion of a person's bone mass can make
14 the bone prone to fracture and/or deformation and cause
15 numerous accompanying adverse effects, including pain and
16 discomfort. One condition, known as osteoporosis, manifests
17 itself as a decrease in bone tissue mass and often leads to
18 fractures of the vertebrae, hip, femur, and distal end of the
19 wrist bone.

20 The World Health Organization defines osteoporosis as
21 comprising four diagnostic categories, normal, osteopenia,
22 osteoporosis, and established osteoporosis, and further defines
23 those categories using diagnostic value ranges. Currently,
24 within the United States, osteoporosis affects about 20-25
25 million people. Osteopenia, a condition where a patient has a
26 lower than normal bone density, afflicts 16% of white women
27 aged 20-29. Within that demographic, less than 1% have
28 osteoporosis. Approximately 38% of women aged 65 have
29 osteopenia while 20% have osteoporosis and, by age 80, the
30 percentage of women with normal bone density decreases to 15%.
31 The percentages depend on race, age, and hormone usage. Due to
32 this condition, one out of every six women will have a hip

1 fracture and one out of every three women will have a vertebral
2 fracture during their lifetime.

3 A person may be at risk of having osteoporosis, or at risk
4 of some degree of bone loss or low bone mass, based upon his or
5 her age, sex, medical history, lifestyle, or family medical
6 history. Specifically, an exemplary set of risk factors that
7 may be used to identify people whose bone mass should be
8 assessed include vertebral compression fracture, age greater
9 than 65 years, family history of osteoporotic fracture,
10 fragility fracture after age 40, malabsorption syndrome,
11 systemic glucocorticoid therapy of more than 3 months, primary
12 hyperparathyroidism, tendency to fall, osteopenia apparent on
13 x-ray film, hypogonadism, and menopause before the age of 45.
14 Other risk factors include past history of clinical
15 hyperthyroidism, rheumatoid arthritis, excessive caffeine
16 intake, low dietary calcium intake, smoking, chronic
17 anticonvulsant therapy, excessive alcohol intake, weight less
18 than 125 lbs., weight loss that is greater than 10 % of total
19 weight at the age of 25, and chronic heparin therapy.

20 Certain medical evaluations can be conducted to determine
21 whether osteoporosis may be present in a patient, including the
22 examination of a patient's height and weight, investigating the
23 presence of pain or deformity in the bones, and identifying
24 underlying medical illnesses using blood cell counts, PTH blood
25 tests, mineral content (calcium, phosphorus, among others), a
26 thyroid test, and vitamin D levels. Once major deterioration
27 has occurred, it is difficult to restore the lost bone. Thus,
28 therapeutic efforts must be directed towards early recognition
29 of the progressive disease so that treatment can be instituted
30 before irreversible structural damage occurs.

31 One approach to diagnosing the existence of osteoporosis
32 in a patient or a patient's susceptibility to bone-loss related

1 ailments, such as bone fractures or osteopenia, is to test a
2 patient's bone and compare the values to established
3 references. Various devices may be used. Ultrasound techniques
4 are advantageous in that they are non-invasive and operate on
5 the principle that the velocity and attenuation of the signal
6 through the patient's bone is a measure of the characteristics
7 of the bone. For treatment purposes, relying solely on the
8 measurement of bone characteristics to compare against
9 established references is disadvantageous because patients
10 often have to wait for a long time to ascertain whether bone
11 formation or resorption is occurring.

12 Another method of diagnosing the deterioration of bone
13 mass is by using biochemical markers indicative of bone
14 turnover. Whenever bone formation or resorption occurs,
15 various chemical reactions occur within the body, which elevate
16 the presence of certain indicators in the body fluids, referred
17 to as biochemical markers, indicating changes in the bone
18 status and, consequently, indicating a greater or lower rate of
19 bone formation or resorption. Using biochemical markers,
20 however, also has considerable disadvantages. It provides
21 little practical information for estimating BMD level.
22 Furthermore, biochemical markers are present in tissues other
23 than bone and can be influenced by non-skeletal processes.
24 Also, unlike densitometers, biochemical markers do not provide
25 information about a specific bone or body regions. Thus,
26 biochemical markers cannot independently be used to diagnose
27 bone depletion and predict fracture risk.

28 Certain systems provide for a biochemical bone measuring
29 unit and a densitometric bone measuring unit to form a bone
30 measuring system that performs biochemical and densitometric
31 assessments of bone material. The system provides practitioners
32 with bone characteristic data to evaluate bone status, and in

1 some instances provides a prognosis as to future bone
2 characteristics. In one embodiment, the system combines the
3 biochemical bone measuring unit and the densitometric bone
4 measuring unit into a single housing. In an alternative
5 embodiment, the densitometric and biochemical units are
6 connected to each other via data communication circuitry and
7 either the densitometric bone measuring unit or the biochemical
8 bone measuring unit has a controller that combines the
9 measurements from each unit to provide bone characteristic
10 data. In another embodiment, the biochemical bone measuring
11 unit and the densitometric bone measuring unit may be
12 individual units that separately perform biochemical and
13 densitometric bone assessments.

14 Despite coupling a bone density measuring and bone marker
15 measuring system, the abovementioned systems have significant
16 disadvantages. Specifically, they merely provide for the use
17 of known measurement systems without providing any type of
18 protocol or method for how to practically integrate the various
19 measurements in a holistic diagnosis and treatment paradigm.

20 Certain protocols do exist for the diagnosis and treatment
21 of osteoporosis. For example, it is recommended that 1)
22 persons over the age of 65 should have a BMD test; 2) persons
23 over the age of 50 with at least one major, or two minor, risk
24 factors should have a BMD test; 3) postmenopausal women with
25 risk factors for fracture should have a BMD test; 4) higher
26 intakes of calcium and vitamin D are recommended, particularly
27 in adults over 50 (calcium 1500 mg/day and vitamin D 800
28 IU/day); and 5) people should participate in exercise,
29 particularly weight-bearing exercises such as brisk walking,
30 running or dancing. Formal protocols, such as the Osteoporosis
31 Risk Assessment Instrument (ORAI) and Simple Calculated
32 Osteoporosis Risk Estimation (SCORE), provide more defined

1 algorithms for identifying persons at risk for osteoporosis
2 based on variables such as the person's age, weight, and
3 estrogen use.

4 However, to properly initiate, conduct, and monitor the
5 effects of a treatment and/or prevention regimen, sufficient
6 knowledge of the state of a person's bone mass, along with rate
7 of increase or decrease is preferred. Current treatment and/or
8 prevention protocols fail to adequately account for or
9 incorporate such information.

10 Although exercising, dietary, and other methods of
11 prevention may exist, there is a need to integrate these
12 various preventive and/or treatment measures with bone
13 measurement techniques to create an integrated osteoporosis
14 treatment protocol. There is also a need for improved methods
15 and systems to determine changes in bone mass in a short period
16 of time, to examine patients and analyze bone deformities to
17 comprehensively assess bone material, and to provide a
18 practitioner with bone data to predict future bone
19 characteristics, to prevent bone loss, to avoid fractures, and
20 to increase bone density.

21

22 SUMMARY OF THE INVENTION

23 The present invention provides improved methods and
24 systems for the diagnosis, prevention, and treatment of
25 osteoporosis. The present invention integrates bone mass
26 measurement techniques with various preventive and
27 treatment measures to create a protocol for the prevention
28 and treatment of a bone related condition such as
29 osteoporosis. Further, the present invention allows for
30 the specific targeting of persons at risk for fracture or
31 bone mass degradation while not requiring mass screening of
32 individuals, thereby providing an efficient and cost-

1 effective approach to osteoporosis for the medical
2 community.

3 In one embodiment, a medical practitioner treats a
4 bone related condition occurring in a patient by measuring
5 a bone characteristic in the patient's bone to yield a
6 first score, such as a T-score; conducting a gait analysis
7 to yield a gait characterization; measuring a bone marker
8 concentration in at least one of the patient's body fluids
9 to yield a bone marker level; and prescribing a therapy
10 based on at least one of the measurement of a bone
11 characteristic level, the gait analysis and the measurement
12 of a bone mass marker concentration. Optionally, the
13 treatment may include designating a future time to repeat
14 the measurement of the bone characteristic, the gait
15 analysis, and the measurement of bone marker level.
16 Further, the steps of measuring a bone characteristic
17 level, conducting a gait analysis and measuring a bone
18 marker concentration may be performed in any order.

19 The bone characteristic may be measured using a bone
20 characteristic measuring unit that comprises a space for
21 housing a portion of the patient, a positioning device for
22 holding the portion, a plurality of ultrasound transducers
23 for transmitting and detecting signals, and an output for
24 outputting the bone characteristic measurement score value.
25 Optionally, the bone characteristic is measured using X-ray
26 absorptiometry (dual or single), quantitative
27 ultrasonometry, or quantitative computed tomography.

28 Preferably, the score utilized in the present
29 invention is a T-score, as determined from a value measured
30 by the bone characteristic measurement unit. The therapy
31 may be prescribed based upon an output of an integrated
32 unit having received the T-score value, the gait

1 characterization, and the bone marker level value. Further
2 optionally, the integrated unit comprises a receiver in
3 data communication with a processing unit and a display
4 unit in data communication with the processing unit.

5 Optionally, the present invention further comprises
6 the step of determining a likelihood of a patient injuring
7 at least one of the patient's bones. Optionally, the bone
8 marker level is measured by a bone marker measurement
9 device that comprises a container containing a body fluid,
10 a mechanism for holding the said container, an analyzer for
11 determining a concentration of an absorbing constituent in
12 a solution, and an output for outputting the bone marker
13 level value.

14 Optionally, the gait is characterized by a gait
15 analysis procedure conducted on a patient wherein the
16 procedure comprises the steps of examining the balance of
17 the patient wherein the patient is standing on both feet,
18 examining the balance of the patient wherein the patient is
19 standing on a first foot, and examining the balance of the
20 patient wherein the patient is standing on a second foot.

21 Optionally, a patient's risk factors are assessed to
22 help determine the therapy. The therapy may be one of
23 recommending life style changes, recommending weight
24 bearing exercises, recommending resistance exercises,
25 recommending increasing calcium intake, recommending
26 increasing vitamin D intake, and recommending at least one
27 of bisphosphonates, calcitonin, estrogen replacement
28 therapy, and raloxifene.

29 Optionally, with respect to the future times for
30 measurement repeats, the present invention includes, within
31 a first pre-defined time period, re-measuring a bone
32 characteristic in at least one of the plurality of bones to

1 yield a second score having a value; within a second pre-
2 defined time period, re-conducting a gait analysis to yield
3 a second gait characterization; and within a third pre-
4 defined time period, re-measuring a bone marker
5 concentration in at least one body fluid of the patient to
6 yield a second bone marker level having a value. The
7 present invention may further include the step of comparing
8 the first T-score to the second T-score, the first gait
9 characterization to the second gait characterization, and
10 the first bone marker level to the second bone marker
11 level, and prescribing a therapy based upon at least one of
12 the comparisons. Further, the first, second and third
13 periods may differ.

14 In another embodiment, the present invention is a
15 system for treating bone related condition of a patient,
16 comprising a bone characteristic measurement unit having an
17 output for communicating a bone characteristic level value,
18 a gait analysis unit having an output for communicating a
19 gait characterization, and a bone marker measurement unit
20 having an output for communicating a bone marker level
21 value.

22 Optionally, the bone characteristic measurement unit
23 comprises a space for housing a portion of said patient, a
24 positioning device connected to said chamber for holding
25 said portion, a plurality of ultrasound transducers for
26 transmitting and detecting signals, and an output for
27 outputting the bone characteristic level value.
28 Optionally, the bone marker measurement unit comprises a
29 container containing a body fluid, an analyzer for
30 determining a concentration of an absorbing constituent in
31 a solution, and an output for outputting the bone marker
32 level value.

1 In another embodiment, the present invention is a
2 method for treating a bone related condition of a patient ,
3 comprising the steps of instructing a medical practitioner
4 to measure a bone characteristic level in at least one of
5 the plurality of bones to yield a score having a value,
6 based upon the value of the score, instructing the medical
7 practitioner to conduct a gait analysis to yield a gait
8 characterization, based upon the value of the score and the
9 gait characterization, instructing the medical practitioner
10 to measure a bone marker concentration in at least one body
11 fluid of the patient to yield a bone marker level having a
12 value, providing the medical practitioner with a plurality
13 of therapies that can be prescribed, and instructing the
14 medical practitioner to designate a future time to repeat
15 the measurement of a bone characteristic level, the gait
16 analysis, and the measurement of bone marker concentration.

17 In another embodiment, the present invention is a
18 method for treating a bone related condition of a patient
19 comprising the steps of measuring a bone characteristic of
20 a bone of a patient to yield a T-score having a value; if
21 the T-score is abnormal, conducting a gait analysis to
22 yield a gait characterization; if the gait characterization
23 is abnormal, measuring a bone marker concentration in at
24 least one body fluid of the patient to yield a bone marker
25 level having a value; prescribing a therapy; and
26 designating a future time to repeat the measurement of a
27 bone characteristic level, the gait analysis, and the
28 measurement of bone marker concentration.

29 The future time to repeat the measurement of a bone
30 characteristic level may be during the twelfth month from
31 the previous measurement. The future time to repeat the
32 gait analysis may include scheduling a series of eight gait

1 analyses over a period of time. The future time to repeat
2 the bone marker measurement may be during the third month
3 from the previous measurement.

4 These and other embodiments shall be described in
5 reference to the drawings and the detailed description.

6

7 **BRIEF DESCRIPTION OF DRAWINGS**

8 These and other features and advantages of the present
9 invention will be further appreciated, as they become better
10 understood by reference to the following detailed description
11 when considered in connection with the accompanying drawings:

12 FIG. 1a is a flowchart depicting data flow for one
13 embodiment of the present invention;

14 FIG. 1b is a flowchart depicting a process of one
15 embodiment of the present invention;

16 FIG. 1c is a flowchart depicting a process of another
17 embodiment of the present invention;

18 FIG. 1d is a flowchart depicting a process of another
19 embodiment of the present invention;

20 FIG. 1e is a flowchart depicting a process of another
21 embodiment of the present invention;

22 FIG. 1f is a flowchart depicting a process of another
23 embodiment of the present invention;

24 FIG. 2 is perspective view of one embodiment of a bone
25 characteristic measuring unit;

26 FIG. 3 is a block diagram illustrating one embodiment
27 of circuitry used in connection with one embodiment of a
28 bone density measuring unit;

29 FIG. 4 depicts one method of assaying bone markers
30 using a plate well;

31 FIG. 5 depicts an exemplary reaction of a label enzyme
32 with a substrate during a labeled immunoassay technique;

1 FIG. 6 provides a perspective view of one embodiment
2 of a bone marker measuring unit;

3 FIG. 7 provides a schematic view of one embodiment of
4 a gait analysis unit; and

5 FIG. 8 is a graph of T-scores relative to percentage
6 of population.

7

8 **Detailed Description:**

9 The present invention provides a protocol for assessing
10 bone characteristics and recommending a treatment regimen using
11 bone characteristic, bone marker, and gait analysis data and
12 existing therapies such as vitamin and mineral supplements,
13 exercise routines, lifestyle modifications, and drug therapies.
14 The present invention will be described with reference to
15 aforementioned drawings. One of ordinary skill in the art
16 would appreciate that the applications described herein are
17 examples of how the broader concept can be applied, that the
18 methods and systems provided herein may be used by a medical
19 practitioner, care-giver, or other health care provider, and
20 that the methods and systems provided herein may be further
21 taught to medical practitioners.

22 Referring to Figure 1a, data flow for one embodiment
23 of the present invention is shown. A patient is first
24 examined with the bone characteristic measuring unit 101a
25 to obtain values from which certain scores, such as the T-
26 score, will be derived. The gait of the patient is then
27 analyzed using a gait analysis unit and/or gait analysis
28 procedure 102a, to assess body imbalance. The level of bone
29 turnover or resorption markers is then determined using the
30 bone marker measuring unit 103a. Finally, prevention and
31 treatment therapies are prescribed 104a. In another
32 embodiment, as shown in Figure 1b, the gait of the patient

1 is analyzed using a gait analysis unit and/or gait analysis
2 procedure 101b, to assess body imbalance. A patient is
3 then examined with the bone characteristic measuring unit
4 102b to obtain values from which certain scores, such as
5 the T-score, will be derived. The level of bone turnover or
6 resorption markers is then determined using the bone marker
7 measuring unit 103b. Finally, prevention and treatment
8 therapies are prescribed 104b.

9 As further described below, one of ordinary skill in
10 the art would appreciate that the order and use of each
11 unit may be dependent upon the data, results, and findings
12 generated in other units, that subsequent diagnoses and
13 tests are scheduled and performed depending on the results
14 obtained herein, and that treatment therapy may vary
15 according to the extent of bone loss as determined by the
16 various methods of diagnosis. For example, if the score
17 measured by the bone density measuring unit is above the
18 required level, bone marker testing and gait analysis may
19 not be performed and a standard prevention therapy may be
20 prescribed. Similarly, if the gait is found to be normal
21 but the score measured by the bone density measuring unit
22 yield abnormal results, the bone marker testing may still
23 be performed and a particular therapy may be prescribed.

24 Figure 1c is a procedural flow diagram, associated
25 with one embodiment of the invention, depicting a course of
26 action when a patient's bone mineral density score, when
27 compared to the appropriate reference value, is comparable
28 to, or above, a corresponding threshold value. The score
29 referred to herein refers to any known scoring method,
30 protocol, or system for evaluating the bone mineral density
31 of a patient. Although the term score is used
32 interchangeably with the term T-score, it is recognized

1 that a T-score is simply one type of score that may used in
2 the present invention. Other scoring approaches,
3 particularly those that are used or endorsed by health
4 organizations, may be used to evaluate a patient's bone
5 mineral density.

6 Referring back to Figure 1c, the patient is examined
7 101c to determine the patient's T-score. If the T-score is,
8 for example, equal to or above a pre-defined threshold
9 "TH", such as -1.0, 0 or a positive number, 102c, or is
10 generally representative of a patient in a low risk
11 category, the patient is classified 103c into the low
12 fracture risk category. As part of the low fracture risk
13 category, the patient may not be required to undergo any
14 further tests. Accordingly, the appropriate exercises,
15 calcium, vitamin D supplements, and other therapies and
16 treatments may be prescribed 104c. The patient may further
17 be advised 105c to come back within a period of time,
18 preferably between 24-36 months or more preferably during
19 the twenty-fourth month, for a second bone characteristic
20 measurement. This process is repeatable throughout the life
21 of a patient, thereby acting as a recurring check on the
22 patient's bone mineral density that is performed
23 periodically.

24 Figure 1d is a procedural flow diagram, associated
25 with another embodiment of the invention, illustrating the
26 course of action in a second instance when the patient's T-
27 score is below a corresponding threshold value, "TH", such
28 as -1.0, zero, or a positive number. The patient is
29 examined 101d to determine the patient's T-score. If the T-
30 score is, for example, below the threshold value 102d,
31 indicating the patient has below normal bone mass, a gait

1 analysis is performed 103d to ascertain the patient's
2 balance 104d.

3 If the gait is normal, the patient is classified 105d
4 into the medium fracture risk category. Optionally, a
5 biochemical bone marker measurement may be taken to
6 determine and record the patient's rate of bone formation.
7 Accordingly, the medical practitioner recommends 106d one
8 or more exercises, calcium, vitamin D supplements, and
9 medications. The patient may be advised to comeback within
10 a first period of time for a gait analysis and within a
11 second period of time for a bone characteristic scan. For
12 example, the patient may be advised to obtain a gait
13 analysis between 9-15 months, or preferably during the
14 twelfth month. The patient may also be advised to obtain a
15 bone characteristic scan between 9-15 months or preferably
16 during the twelfth month. Further, if applicable, the
17 patient may be advised to obtain a bone marker test between
18 2-4 months or preferably during the third month.

19 Preferably, the patient continues the treatment and testing
20 regimen until an improvement in the T-score is achieved.

21 If the gait is poor and, therefore, indicative of an
22 imbalance which could lead to a fall and possibly bone
23 fractures, the patient is classified 107d into the high
24 fracture risk category. Biochemical bone markers are then
25 measured 109d and compared to an expected range or reference
26 values 110d. Where the bone marker concentrations indicate a
27 normal condition, the patient may be prescribed 111d calcium,
28 vitamin D supplements, exercise, other regimens, and
29 medications. The patient may further be advised to comeback
30 within a first period of time for a gait analysis 108d, a
31 second period of time for a bone marker analysis 113b, and a
32 third period of time for a bone characteristic scan 108d. For

1 example, the patient may be advised to obtain a gait analysis
2 between 1-4 months and preferably during the second month.
3 Alternatively, the patient may be placed on a gait analysis
4 schedule that involves performing a gait analysis once every
5 two weeks for sixteen consecutive weeks, or preferably,
6 performing a gait analysis once a week for eight consecutive
7 weeks. Where the patient is placed on a gait analysis
8 schedule, the patient may have, for example, a medical
9 practitioner conduct the gait analysis. Alternatively, the
10 patient may perform a self-gait analysis using, for example, a
11 pressure sensing platform device, which will be described in
12 further detail below, and report the result to the medical
13 practitioner.

14 The patient may also be advised to obtain a bone
15 characteristic scan between 9-15 months or preferably during
16 the twelfth month. Further, the patient may be advised to
17 obtain a bone marker test between 2-4 months or preferably
18 during the third month. Preferably, the patient continues the
19 treatment and testing regimen until an improvement in the
20 marker level, gait, and/or T-score is achieved.

21 Alternatively, where the bone marker concentrations
22 indicate a borderline or abnormal condition, the patient may be
23 prescribed 112b certain calcium and vitamin D supplements along
24 with strict medicinal treatment regime. The patient may further
25 be advised to comeback within a first period of time for a gait
26 analysis 108d, a second period of time for a bone marker
27 analysis 114b, and a third period of time for a bone
28 characteristic scan 108d. For example, the patient may be
29 advised to obtain a gait analysis between 1-4 months and
30 preferably during the second month. Alternatively, the patient
31 may be placed on a gait analysis schedule that involves
32 performing a gait analysis once every two weeks for sixteen

1 consecutive weeks, or preferably, performing a gait analysis
2 once a week for eight consecutive weeks. Where the patient is
3 placed on a gait analysis schedule, the patient may have, for
4 example, a medical practitioner conduct the gait analysis.
5 Alternatively, the patient may perform a self-gait analysis
6 using, for example, a pressure sensing platform device, which
7 will be described in further detail below, and report the
8 result to the medical practitioner.

9 The patient may also be advised to obtain a bone
10 characteristic scan between 9-15 months or preferably during
11 the twelfth month. Further, the patient may be advised to
12 obtain a bone marker test between 2-4 months or preferably
13 during the third month. Preferably, the patient continues the
14 treatment and testing regimen until an improvement in the
15 marker level, gait, and/or T-score is achieved.

16 Referring to Figure 1e, a procedural flow diagram,
17 associated with another embodiment of the invention, is
18 shown. A gait analysis 101e is performed to ascertain the
19 patient's balance and propensity to fall and be susceptible
20 to bone fractures. Next, the patient's T-score is examined
21 102e. If the gait analysis and the T-score is determined
22 to be normal, the patient is classified 103e into a low
23 risk fracture category. Accordingly, the medical
24 practitioner may recommend 104e one or more exercises,
25 calcium, vitamin D supplements, medications, and other
26 treatments or therapies. The patient may further be
27 advised 105e to comeback within a period of time for a gait
28 analysis and a bone characteristic scan. For example, the
29 patient may be advised to obtain a gait analysis and a bone
30 characteristic scan after 24 months. This process is
31 repeatable throughout the life of a patient, thereby acting
32 as a periodic check on the patient's condition.

1 If the T-score examined at 102e is below a threshold
2 value, the patient is classified into a medium fracture
3 risk category. A biochemical bone marker measurement is
4 also taken to record the patient's rate of bone formation.
5 Based on part or all of the measured values or analysis
6 results, the medical practitioner may recommend one or more
7 exercises, calcium, vitamin D supplements, and medications.
8 The patient may be advised to come back within a first
9 period of time for a gait analysis, a second period of time
10 for a bone characteristic scan, and a third period of time
11 for a bone marker analysis. For example, the patient may
12 be advised to obtain a gait analysis between 9-15 months,
13 or preferably during the twelfth month. The patient may
14 also be advised to obtain a bone characteristic scan
15 between 9-15 months, or preferably during the twelfth
16 month. Further, the patient may be advised to obtain a
17 bone marker test between 2-4 months or preferably during
18 the third month. This process is repeatable and is
19 preferably continued until an improvement in the T-score is
20 achieved.

21 Referring to Figure 1f, a procedural flow diagram,
22 associated with another embodiment of the invention, is shown.
23 A gait analysis 101f is performed to ascertain the patient's
24 balance and propensity to fall and be susceptible to bone
25 fractures. If the gait is determined to be abnormal 102f, the
26 patient is examined 103f to determine the patient's T-score.
27 If the T-score is equal to or above the threshold value 104f,
28 indicating the patient at least has normal bone mass, the
29 patient is categorized in a medium risk category 105f and a
30 medical practitioner may recommend 106f one or more exercises,
31 calcium, vitamin D supplements, medications, therapies, and
32 treatments. The patient may further be advised 107f to comeback

1 within a first period of time for a gait analysis and within a
2 second period of time for a bone characteristic scan. For
3 example, the patient may be advised to obtain a gait analysis
4 between 1-4 months and preferably during the second month.
5 Alternatively, the patient may be placed on a gait analysis
6 schedule that involves performing a gait analysis once every
7 two weeks for sixteen consecutive weeks, or preferably,
8 performing a gait analysis once a week for eight consecutive
9 weeks. Where the patient is placed on a gait analysis
10 schedule, the patient may have, for example, a medical
11 practitioner conduct the gait analysis. Alternatively, the
12 patient may perform a self-gait analysis using, for example, a
13 pressure sensing platform device, which will be described in
14 further detail below, and report the result to the medical
15 practitioner.

16 The patient may also be advised to obtain a bone
17 characteristic scan between 24-36 months or preferably
18 during the twenty-fourth month. Preferably, the patient
19 continues the treatment and testing regimen until an
20 improvement in the gait is achieved.

21 If the T-score is below the threshold value 104f,
22 indicating the patient has below normal bone mass, the patient
23 is categorized 107f into a high risk category. Biochemical
24 bone markers are then measured 109f and compared to reference
25 values 110f. Where the bone marker concentrations indicate a
26 normal condition, the patient may be prescribed 111f calcium,
27 vitamin D supplements, exercise, other regimens, and
28 medications. The patient may further be advised to comeback
29 within a first period of time for a gait analysis 108f, a
30 second period of time for a bone marker analysis 113f, and a
31 third period of time for a bone characteristic scan 108f. For
32 example, the patient may be advised to obtain a gait analysis

1 between 1-4 months and preferably during the second month.
2 Alternatively, the patient may be placed on a gait analysis
3 schedule that involves performing a gait analysis once every
4 two weeks for sixteen consecutive weeks, or preferably,
5 performing a gait analysis once a week for eight consecutive
6 weeks. Where the patient is placed on a gait analysis
7 schedule, the patient may have, for example, a medical
8 practitioner conduct the gait analysis. Alternatively, the
9 patient may perform a self-gait analysis using, for example, a
10 pressure sensing platform device, which will be described in
11 further detail below, and report the result to the medical
12 practitioner. The patient may also be advised to obtain a bone
13 characteristic scan between 9-15 months or preferably during
14 the twelfth month. Further, the patient may be advised to
15 obtain a bone marker test between 2-4 months or preferably
16 during the third month. Preferably, the patient continues the
17 treatment and testing regimen until an improvement in the
18 marker level, gait, and/or T-score is achieved.

19 Alternatively, where the bone marker concentrations
20 indicate a borderline or abnormal condition, the patient may be
21 prescribed 112f certain calcium and vitamin D supplements along
22 with a medicinal treatment regime. The patient may further be
23 advised to comeback within a first period of time for a gait
24 analysis 108f, a second period of time for a bone marker
25 analysis 114f, and a third period of time for a bone
26 characteristic scan 108f. For example, the patient may be
27 advised to obtain a gait analysis between 1-4 months and
28 preferably during the second month. Alternatively, the patient
29 may be placed on a gait analysis schedule that involves
30 performing a gait analysis once every two weeks for sixteen
31 consecutive weeks, or preferably, performing a gait analysis
32 once a week for eight consecutive weeks. Where the patient is

1 placed on a gait analysis schedule, the patient may have, for
2 example, a medical practitioner conduct the gait analysis.
3 Alternatively, the patient may perform a self-gait analysis
4 using, for example, a pressure sensing platform device, which
5 will be described in further detail below, and report the
6 result to the medical practitioner. The patient may also be
7 advised to obtain a bone characteristic scan between 9-15
8 months or preferably during the twelfth month. Further, the
9 patient may be advised to obtain a bone marker test between 2-4
10 months or preferably during the third month. Preferably, the
11 patient continues the treatment and testing regimen until an
12 improvement in the marker level, gait, and/or T-score is
13 achieved.

14 The present invention further contemplates and covers
15 processes that performs a bone mineral density analysis, gait
16 analysis and/or a bone marker analysis irrespective of whether
17 the first analysis performed yields a normal result. Moreover,
18 the present invention covers processes whereby the bone
19 measuring process, the gait analysis and the bone marker
20 measuring process may be sequenced in any suitable order. For
21 example, the bone marker test may be performed first followed
22 by a bone mineral density test and the gait analysis.

23 Furthermore, the present invention contemplates and covers
24 processes whereby the second or subsequent bone characteristic
25 measurement(s) may or may not be taken from the same bone that
26 was examined previously. However, it is preferred to measure
27 the bone characteristic from the same bone and to use the same
28 machine or type of machine to minimize variation in the
29 collected data.

30 As provided in greater detail below, the present invention
31 utilizes a plurality of measurement techniques to provide
32 methods and systems designed to help medical practitioners,

1 such as doctors, nurses, technicians, chiropractors, and other
2 health care professionals, diagnose and treat osteoporosis.
3 Because osteoporosis is an endemic condition, the whole body of
4 a patient is generally affected by bone degradation.
5 Accordingly, it is possible to predict the risk of injuring one
6 bone, for example the hip bone, by examining or measuring the
7 bone characteristic of another bone, for example the heel bone.
8 Combining these diagnostic tests increases the likelihood of
9 identifying bone mass degradation in one of a plurality of
10 bones of a patient early in the process, preventing bone
11 fractures or other injuries, and stabilizing or reversing the
12 bone loss process. The present invention further helps cost-
13 effectively address bone loss related ailments by selecting
14 high risk individuals and avoiding mass screening or
15 unnecessary examination.

16 A plurality of bone mass measurement devices exist that
17 can be used to determine a patient's bone characteristic. X-
18 ray based systems operate on the principle that bone attenuates
19 or absorbs ionizing radiation and, therefore, the bone
20 characteristic, which is referred to as bone mineral density,
21 can be determined based upon the amount of radiation that
22 passes from a X-ray source, through the bone, and into a
23 radiation detector. In one embodiment of the present
24 invention, the bone mass measurement unit comprises a device
25 employing single energy X-ray absorptiometry (SXA). SXA uses
26 an X-ray tube to produce a single photon beam directed at a
27 body part immersed in a water bath to simulate a uniform soft-
28 tissue thickness. SXA is effectively used to image distal
29 skeletal sites, such as the calcaneus, and typically generates
30 bone mineral density measurements in terms of grams per
31 centimeter squared (g/cm^2).

1 In another embodiment of the present invention, the bone
2 mass measurement unit comprises a device employing dual energy
3 X-ray absorptiometry (DXA). DXA measurements can be performed
4 at central sites, such as the spine and hip, or at peripheral
5 sites, such as the forearm, calcaneus, or wrist and typically
6 generates bone mineral density measurements in terms of grams
7 per centimeter squared (g/cm^2).

8 In another embodiment of the present invention, the bone
9 mass measurement unit comprises a device employing quantitative
10 computed tomography (QCT). QCT generates an image of a thin
11 transverse slice through the body and measures true volumetric
12 bone density (e.g., a three-dimensional measurement expressed
13 in g/cm^3) derived from tissue attenuation measurements. Because
14 attenuation is dependent on tissue density and composition, QCT
15 allows for distinct measurements of both trabecular and
16 cortical bone density of several sites in the body. QCT is
17 available in either a single-energy mode or dual-energy mode,
18 which has a higher radiation dose. One of ordinary skill in
19 the art would appreciate that other photon radiation based bone
20 measurement approaches exist, including radiographic
21 absorptiometry and single and dual photon absorptiometry.

22 X-ray based systems have, however, several
23 disadvantages. They are often relatively expensive,
24 require a large amount of operational space, and lack
25 portability. Moreover, because X-ray devices emit ionizing
26 radiation, they may require a licensed technician to
27 operate the equipment, limiting the range of users.

28 In a preferred embodiment, quantitative ultrasonometry
29 (QUS) is used to measure a patient's bone characteristic,
30 which is referred to as either a quantitative ultrasound
31 index (QUI) or stiffness index (SI), by, for example,
32 measuring the propagation of an ultrasound pulse through

1 the patient's heel. As opposed to X-ray based systems, QUS
2 does not rely on ionizing radiation. Instead, it uses
3 broadband ultrasound attenuation (BUA), which is a measure
4 of the attenuation of the ultrasound pulse through the
5 bone, and speed of sound (SOS), which is a measure of the
6 time the sound pulse takes to travel through the heel.
7 Because the velocity of sound is higher in healthy bone,
8 QUS can measure bone mass and give some information about
9 bone microarchitecture. More specifically, in patients
10 with osteoporosis, the attenuation of the sound wave is
11 reduced and the SOS value is smaller, thereby affecting
12 both the BUA and SOS values. QUS is typically conducted on
13 the patient's heel, finger and/or tibia.

14 In one embodiment, because the speed of sound is dependent
15 upon the degree of connectivity of the trabeculae, the SOS
16 value can be used to evaluate the connectivity and elasticity
17 of bone. The speed of the ultrasonic acoustic signal is
18 measured at a number of frequencies at multiple locations.
19 Typically, normal bone has higher SOS than osteoporotic bone
20 because of better linkage.

21 Additionally, because the attenuation of ultrasound is
22 dependent upon bone structure, the BUA value can be used to
23 evaluate bone density and obtain some information about bone
24 structure. The attenuation of the ultrasonic acoustic signal
25 is measured at one or more frequencies at multiple locations.
26 Typically, normal bone has higher attenuation than osteoporotic
27 bone because of its rigid composition. The BUA may then be
28 calculated as the slope of the attenuation as a function of the
29 ultrasonic frequency.

30 To evaluate the strength, structure, and mineral content
31 of a patient's bones, and therefore, whether the individual is
32 suffering from insufficient bone density, some ultrasound

1 densitometers combine BUA and SOS measurements to determine the
2 quantitative bone characteristic from which a T-score is
3 determined. Certain QUS systems generate a quantitative
4 ultrasound index (QUI) or stiffness index (SI), which are
5 ratios of the BUA value to the SOS value and are considered
6 equivalents to bone mineral density measurements. One of
7 ordinary skill in the art would appreciate that other
8 combinations of BUA and SOS can be used to determine bone
9 mineral density measurements. According to the World Health
10 Organization (WHO), a T-score is defined as the number of
11 standard deviations from the average bone density value of
12 young (25 - 30 year old) individuals of the same sex and
13 ethnicity. One of ordinary skill in the art would appreciate
14 that the value of the T-score provides a relative assessment of
15 how much greater, or lower, the patient's bone density is as
16 compared to the average bone density of a young individual.
17 The T-score may be determined from a bone characteristic
18 measurement, such as bone mineral density, quantitative
19 ultrasound index, or stiffness index.

20 Medical practitioners can use the T-score to diagnose the
21 existence of bone thinning or osteoporosis. Referring to
22 Figure 8, a T-score of above -1.0 810 indicates substantially
23 no bone deterioration and the patient is normal. The patient
24 may be defined as having a low bone density 820, referred to as
25 osteopenia, if the T score is between -1.0 and -2.5. Finally,
26 the patient may be defined as having a very low bone density
27 and substantial bone loss 830, referred to as osteoporosis, if
28 the T score is less than -2.5. Although the graph is presented
29 in terms of standard deviations relative to a bone mineral
30 density level, one of ordinary skill in the art would
31 appreciate that similar graphs are applicable to other bone

1 characteristic data, such as quantitative ultrasound index or
2 stiffness index.

3 There are numerous ways to interpret bone characteristics
4 measurements and medical practitioners may use different
5 metrics for determining what is, and is not, significant bone
6 loss warranting treatment. For example, if the bone
7 characteristic is measured for multiple areas of a patient's
8 body, thereby deriving multiple T-scores, certain health care
9 providers may use the lowest T score to diagnose the patient.
10 Therefore, if a T score of -3 were obtained at the hip and -2
11 were obtained at the arm, the doctor may use the -3 T score as
12 a basis to conclude the patient is suffering from osteoporosis.

13 Additionally, there may be other ways to define a
14 reference level against which to compare a patient's bone
15 characteristic values and, therefore, other ways to represent
16 the relative state of a patient's bone condition. For example,
17 the bone characteristic data may also be used to determine a Z
18 score, which is defined as the number of standard deviations
19 from the average bone density value of individuals of the same
20 age, sex, and ethnicity. The present invention is not limited
21 to the specific reference definitions described herein.

22 While a plurality of different bone characteristic
23 measurement devices may be used in the present invention, it
24 should be noted that the bone characteristic data, and
25 therefore the T-scores, generated in different devices may vary
26 a great deal. Specifically, a patient examined with QCT may
27 yield a lower T-score than QUS. Therefore, T-scores must be
28 interpreted in light of the devices used.

29 T-scores must further be interpreted in light of which
30 part of the body had been measured. The most commonly measured
31 sites, the axial and appendicular skeleton, consist of the bone
32 and cartilage in the head, neck, and trunk (axial) and the

1 shoulder blade, collarbone, the upper and lower limbs, and the
2 pelvis (appendicular). Peripheral areas of the appendicular
3 skeleton are also measured and include the forearm, phalanges,
4 os calcis, and most preferably calcaneus. Bone characteristic
5 measurements of the axial or appendicular skeleton or of the
6 peripheral areas can be useful in making a clinical decision
7 regarding intervention for the prevention or treatment of
8 osteoporosis.

9 Further, it should be noted that the bone characteristic
10 measurement is preferably conducted in the context of a full
11 physical exam so that the root causes for bone loss can be
12 determined. In certain cases, low bone characteristic values
13 may be caused by a plurality of other conditions, including
14 hyperthyroidism, multiple myeloma, Cushing's syndrome,
15 hyperparathyroidism, rickets, premature menopause, vitamin D
16 deficiency, and ankylosing spondylitis.

17 Referring to figure 2, a perspective view of the bone
18 characteristic measuring unit of the present invention is
19 shown. The bone characteristic measuring unit 200 comprises
20 a region 201, reference liquid medium 202, positioning
21 device 203, and ultrasound transducers 204 and 205. The
22 region 201 contains a reference liquid medium 202 in which
23 the patient's heel bone, or calcaneus, 209 is immersed. The
24 positioning device 203 is provided to support the patient's
25 calcaneus. The first ultrasound transducer 204 and the
26 second ultrasound transducer 205 are positioned on either
27 side of the patient's calcaneus 209 and are held by
28 suitable supports not shown. The transducers 204 and 205
29 are connected by mechanical linkages to motors enabling
30 them to scan a rectangular area generally corresponding to
31 the portion of the calcaneus to be scanned. One of ordinary
32 skill in the art would appreciate that there can be arrays

1 of transducers for sending and receiving the ultrasound
2 signals on both sides of the body portion being scanned.
3 One of ordinary skill in the art would also appreciate that
4 the bone characteristic measuring unit can comprise
5 ultrasound transducers that are fixed in place and scan a
6 singular area of the target scan region, such as the
7 calcaneus.

8 Referring to figure 3, the block diagram illustrating
9 the circuitry used in connection with the above described
10 bone characteristic measuring unit is shown. The circuitry
11 300 comprises digital analog converter 301, voltage
12 controlled sine-oscillator (VCO) 302, signal control unit
13 303, power amplifier 304, receiver amplifier 305, digital
14 signal processor (DSP) 306, transducers 307 and 308, motor
15 control block 309, temperature probe 310, and display panel
16 311. The digital analog converter 301 supplies power to the
17 VCO 302, which can produce signals having variable
18 frequencies. The signal control unit 303 regulates these
19 signals and feeds them to the transducers 307 and 308 via
20 the power amplifier 304. The receiver amplifier 305
21 amplifies the signal received from the transducers, which
22 is sampled and read into the DSP 306, which examines the
23 signal and adjusts the gain. The motor control block 309 is
24 used for positioning the transducers in the vertical and
25 horizontal directions so that a selected area can be
26 scanned by moving the transducers in the scanning pattern.
27 The temperature probe 310 is used to register the
28 temperature of the water or other reference liquid around
29 the calcaneus.

30 Operationally, a scan is performed by moving the
31 transducers 307 and 308 synchronously in the horizontal and
32 vertical directions over an area of the area being scanned,

1 most preferably the patient's calcaneus. While in motion,
2 signals are emitted from the first transducer 307 and are
3 received by the second transducer 308 in transmission mode
4 and received back by the transmitting transducer in pulse
5 echo or reflection mode. Attenuation is measured at each
6 location at a desired number of frequencies, preferably in
7 the range of 100 kHz to 1 MHz, more preferably between 200
8 and 600 kHz. Broadband ultrasonic attenuation (BUA) may
9 then be calculated by the DSP 306 at each scanned location
10 as the slope of the attenuation as a function of the
11 ultrasound frequency. Speed of sound (SOS) is also
12 calculated by the DSP 306. The DSP 306 then utilizes BUA
13 and SOS to determine a value, such as QUI, SI, or BMD, from
14 which the T-score can be derived.

15 The calcaneus is analyzed because that it has high
16 content of spongy trabecular bone. Also, because of the
17 prevalence of osteoarthritic changes in the central
18 skeleton, measurements at the calcaneous provide a more
19 accurate assessment because it is a weight bearing bone.
20 Moreover, assessments of fracture risk at the calcaneus
21 site are equally predictive of the fracture risk in the
22 entire skeleton. However, any part of the body may be
23 used, including the forearm or other appendages.

24 One of ordinary skill in the art would appreciate that the
25 present invention can employ any type of densitometer,
26 including varying designs for QUS, QCT, DXA, or SXA systems.
27 One would further appreciate that the areas of the body that
28 could be used to generate a T-score include any part of the
29 patient's skeleton.

30 In a preferred embodiment, the T-score generated by
31 measurements made with the densitometer is used together with
32 the gait analysis data to identify an individual at high risk

1 for bone fracture and to increase the specificity of estimated
2 bone loss. Patients having a decreased bone mass have an
3 increase fracture risk for both vertebral and nonvertebral
4 sites, such as the wrist or hip. Because fracture risk is
5 inversely proportional to bone density, for each standard
6 deviation below the young adult peak mean bone mass, the risk
7 of fracture increases up to three fold. The most common sites
8 of osteoporotic fractures are the wrist, spine and hip. While
9 most fractures can be resolved with surgery, hip fractures may
10 prevent a person from walking independently and spine fractures
11 may result in curvature of the spine (dowager's hump) or loss
12 of height.

13 Gait analysis is conducted to inspect a patient's gait,
14 namely the patient's particular manner of moving on foot, and
15 generate a gait characterization. The measurements provide
16 details on the bone joint angles/positions and relative risk
17 for falling. A patient determined to have low or rapidly
18 decreasing bone mass by the densitometer is analyzed using such
19 a gait analysis system to further determine the patient's
20 susceptibility to bone fractures. Patients with more negative
21 T scores and imbalance during walking are at greater risk of
22 breaking a bone during an accident or fall.

23 In one embodiment, the gait analysis is conducted by
24 employing an observational approach. The individual is made
25 to stand on both feet and the posture is analyzed for
26 balance, stability, symmetry, and foot support pattern.
27 Subsequently, the individual is made to stand on one foot
28 at a time and again each stance is observed for the
29 distribution of forces below the foot. Observational gait
30 analysis is generally more reliable when it focuses on
31 proximal segments instead of distal segments.

1 In a second embodiment, the gait analysis is conducted
2 by employing a device having at least two platforms capable
3 of sensing pressure. As known to those of ordinary skill
4 in the art, a patient stands on the platforms, with one
5 foot on a first platform and a second foot on a second
6 platform, thereby exerting pressure on the two platforms.
7 A lack of stability, symmetry, or foot support pattern can
8 be determined by analyzing the pressure differential
9 detected by the two platforms. The platforms can be
10 pressures pads, scales, or other measurement devices.
11 Further, these type of platform devices may be used at the
12 patient home to allow the patient to perform a self-gait
13 analysis.

14 To facilitate the patient to perform a self-gait test,
15 these platform devices may be portable and be used in the
16 patient's home.

17 In another embodiment, shown in Figure 7, the gait
18 analysis system 700 includes detectors, such as
19 electrogoniometers, 701, infrared motion cameras 702, force
20 platforms 703, sensors 704, processing unit 705, and
21 display panel 706. The electrogoniometers 701 are secured
22 to the hip, knee, and ankle joints of both the legs of the
23 patient and function as reflective markers during walking.
24 The infrared motion cameras 702 detect the movement of
25 joints by monitoring the electrogoniometers 701. The force
26 platforms 703, recessed into the floor of the system,
27 measure the amount of force each foot applies to the
28 ground. The sensors 704, fixed to the shoe soles, measure
29 the distribution of pressure beneath various parts of the
30 foot. An amplifier unit connects the measuring equipment
31 with the processing unit 705.

1 It is hereby contemplated that the infrared cameras 702,
2 the force platforms 703, and the shoe sensors 704 transmit the
3 detected data to the processing system 705. The processing
4 system 705 reconstructs the gait graphically in 3D visual form
5 and determines the kinematics, joint angle/position changes,
6 joint movement and powers, and extended and undersized bones.
7 The processed data is displayed on the display panel. Using
8 the processed data, a medical practitioner can make a gait
9 characterization, taking into account the patient's posture,
10 balance, stability, symmetry, and foot support pattern.

11 Once the patient's T-score has been derived and,
12 optionally, gait has been characterized, a patient may require
13 a determination of bone turnover. Determinations of bone
14 turnover rates are performed utilizing conventional serum
15 and/or urine laboratory tests, including fasting
16 calcium/creatinine, hydroxyproline, alkaline phosphatase and/or
17 osteocalcin/bone growth protein. Bone erosion markers,
18 measured in urine, include deoxypyridinoline collagen
19 crosslinks (DPD), N-telopeptides of type 1 bone collagen (NTX), and C-telopeptides of type 1 bone collagen (CrossLaps) and
20 measure breakdown products of bone collagen. Bone formation
21 markers, measured in serum, include osteocalcin and bone
22 specific alkaline phosphatase, which are secreted by
23 osteoblasts (bone forming cells) and indicate the activity of
24 these cells. High levels of bone turnover markers indicate that
25 the patient is a fast bone loser and that the hip fracture risk
26 may be doubled. The lab tests generally utilize standard high
27 pressure liquid chromatography (HPLC) techniques.

28 Biochemical assessments of bone characteristics can be
29 made by various methods such as enzyme-linked immunosorbent
30 assays (ELISA), radioimmunoassays, immunoradiometric assays,
31 labeled immunoassay technique, capillary electrophoresis
32

1 technique, western blotting technique, and florescent
2 microscopy technique. Various types of assays such as chemical,
3 enzymatic, immunochemical, and radioimmuno assays may be used
4 on a sample plate to detect the level of markers in the body
5 fluids. For example, chemical assays may detect phosphorous and
6 calcium. Radioimmuno assays can detect radioisotopes such as
7 I^{125} , H^3 , and C^{14} . Enzymatic assays can detect the action of
8 enzymes such as alkaline phosphatase and pyridoniline.
9 Immunochemical assays may detect biological compounds by
10 monoclonal or polyclonal antibodies or specific receptor
11 proteins. As known by those skilled in the art, several bone
12 specific assays have been developed which enable bone turnover
13 to be evaluated with an immunoassay format.

14 In one embodiment, a labeled immunoassay technique
15 employs a plate containing wells for detecting biochemical
16 markers. Referring to Figure 4, one method of assaying
17 biomarkers using a plate well 400 is shown. In Figure 4a
18 antibodies 401a are fixed to the bottom of the well 400.
19 Biomarker samples containing object antigens 402a are
20 introduced to the well. Figure 4b shows antigen-antibody
21 reaction and each object antigen 402b combines with a solid
22 phase antibody 401b. After antigen-antibody reaction, the
23 liquid layer 403b is removed leaving the combined antigen
24 401b and antibody 402b. Figure 4c depicts the effect of
25 introduction of labeled antibodies 403c, such as color
26 reagents, in the well, which combine with object antigens
27 402c. Figure 4d depicts antigen-antibody reaction so that
28 the object antigen 402d is sandwiched between the
29 antibodies 401d and 403d. Subsequently, the liquid layer
30 404d is removed. Figure 4e shows the well 400 containing
31 labels 403e, which are examined. The number of labels is

1 proportional to the quantity of the object antigens, i.e.
2 biomarkers.

3 In one embodiment, multiwell plate assays are
4 employed. The plate has antibodies fixed in the wells to
5 capture and detect markers. The antibodies are compatible
6 with the markers to be detected. These antibodies are
7 produced by certain animals in response to an antigen, and
8 are collected, purified, and used as a reagent in
9 immunoassays. The antibodies are pre-applied to the surface
10 of plate wells. Body fluid such as urine or blood is then
11 applied to the surface of the wells. To detect and amplify
12 the initial antigen-antibody reaction in an immunoassay,
13 antibodies must be labeled. Antibodies are labeled using
14 radioisotopes such as I^{125} and H^3 , fluorescent dyes, such as
15 fluorescein and rhodamine, and enzymes such as horseradish
16 peroxidase (HRP) and alkaline phosphatase (AP). The label
17 on an antibody catalyzes the chemical conversion of a
18 substrate into a product, which can be examined.

19 Figure 5 shows the reaction of a label enzyme with a
20 substrate. The enzyme 501, used as a label, reacts with the
21 antigen-antibody mixture 502 to create the product 503. A
22 photomultiplier tube or a spectrophotometer 504 then
23 detects the florescence or color of the product 503. The
24 extent of color or fluorescent intensity is proportional to
25 the quantity of the biochemical marker.

26 Figure 6 shows one embodiment of the bone marker
27 measuring unit. The bone marker measuring unit 600 includes
28 housing 601, sample plate 602, access port 603, plate
29 reader 604, display panel 605, and switches 606 and 607.
30 The access port 603 is designed in such a way so as to
31 receive the sample plate 602 treated with the biochemical
32 marker. The plate reader 604 is built into the housing

1 below the access port 603 and spectrophotometrically
2 measures the optical density or absorbance of the reactions
3 occurring in the plate wells. The plate reader 604 is tuned
4 to a specific wavelength for a particular assay and is used
5 to measure the amount of light absorbed by the reaction of
6 label enzyme with the substrate. The results generated by
7 the plate reader 604 are proportional to the concentration
8 of the absorbing constituent in the solution. The results
9 provided by the plate reader 604 are transmitted to the
10 display panel 605, which displays the bone marker readings.
11 The switch 606 is an ON/OFF switch. The switch 607 is a
12 TEST switch and is used to activate the plate reader to
13 read the sample plate.

14 In another embodiment of the bone marker measuring
15 unit, a sample of body fluid such as blood or urine is
16 collected in a test tube. The test tube containing the body
17 fluid is placed in an analyzer, which determines the
18 concentration of the bone formation and resorption markers.
19 The concentration of these markers is then compared to the
20 reference values to determine the bone marker levels. This
21 embodiment is particularly useful in determining the bone
22 marker levels on small scale such as laboratories.

23 Preferably, all of the tests, including the bone scan,
24 gait analysis, and bone marker tests, are performed at the
25 point of care. Specifically, it is preferred that a health
26 care provider can conduct a set of test and provide a
27 patient with a specific set of therapies, recommendations,
28 treatments, or prescriptions prior to the patient leaving
29 the health care provider's premises.

30 The present invention may optionally use an integrated
31 therapy unit to provide prevention and treatment
32 recommendations based on the diagnosis by the above

1 described bone characteristic measuring, gait analysis, and
2 bone marker measuring units. The treatment recommendations
3 for the prevention and treatment of osteoporosis include
4 life style changes, exercises, calcium and vitamin
5 supplements, and medications. In one embodiment, the
6 integrated therapy unit comprises a receiver, for receiving
7 data outputs from each of the bone characteristic and bone
8 marker measurement units, and the gait analysis technique,
9 a processor for relating the received data outputs to a
10 recommended treatment protocol, set of prescriptions, or
11 other treatments, and a display for displaying such
12 recommendations.

13 In one embodiment, the treatment recommendations are
14 stored in a data source. The treatment recommendations may
15 be stored in any data structure, including spreadsheet,
16 database or other table formats. In an exemplary use, data
17 is received that indicates the patient's state of bone mass
18 and the gait condition. The processor references a lookup
19 table, in accordance with the data, to determine whether
20 the patient is in a high-risk category. If so, bone marker
21 measurement is then performed to produce marker
22 concentration levels. Based upon the gait
23 characterization, bone density levels, and bone marker
24 levels, or based upon their values relative to a reference
25 level, the processor references the lookup table and
26 retrieves an appropriate protocol particular to the
27 patient's values. Such a protocol is output on the display
28 device as treatment recommendations. These recommendations
29 are then used by practitioners to prescribe treatment
30 regimens and advice patients to comeback for re-
31 examination. One of ordinary skill in the art would
32 appreciate that a plurality of other structural elements

1 would exist in such a processing unit to insure
2 operability, including memory units, data transmission
3 buses, and other data reception, transmission, and
4 processing elements.

5 One of ordinary skill in the art would also appreciate
6 that data from different examination techniques can be
7 obtained separately and input manually in the integrated
8 therapy unit. Also, the practitioners can analyze the three
9 different types of data manually, corresponding to a
10 patient's values, using the protocols from the lookup
11 tables.

12 Recommendations can include life style changes such as
13 quitting cigarette smoking and alcohol intake that help in
14 reducing bone loss. Smoking cigarettes can lead to bone
15 weakening. Alcohol consumption is also known to affect
16 bones. Therefore, ceasing alcohol consumption and smoking
17 can help in decreasing bone loss.

18 Recommendations can also include a proper exercise
19 regimen that helps in building and maintaining normal bone
20 mass and density. Typically, weight bearing and resistance
21 exercises are prescribed. In the weight bearing exercises,
22 bones and muscles work against gravity. Jogging, walking,
23 stair climbing, dancing, racquet sports, and hiking are
24 examples of weight bearing exercises with different degrees
25 of impact. The second type of exercises is resistance
26 exercises that use muscular strength to improve muscle mass
27 and strengthen bone. These activities include weight
28 lifting.

29 Recommendations can also include a dietary changes
30 that help increase bone mass. A balanced diet rich in
31 calcium and vitamin D helps in preventing bone loss.
32 Depending on the age, an appropriate calcium intake falls

1 between 1000 and 1300 mg a day. Foods such as low-fat
2 milk, cheese, broccoli, orange juice, and cereals are rich
3 in calcium. Calcium supplements in the form of oral pills
4 may also be consumed.

5 Recommendations can also include increased vitamin
6 intake. Vitamin D plays a major role in calcium absorption
7 and bone health. It allows calcium to leave the intestine and
8 enter the bloodstream and helps kidneys in resorbing calcium.
9 Vitamin D is manufactured in the skin following direct
10 exposure to sunlight. Usually 10-15 minutes exposure of the
11 body two to three times a week is enough to satisfy the body's
12 vitamin D requirement. The major food sources of vitamin D are
13 vitamin D-fortified dairy products, egg yolks, saltwater fish
14 and liver. Some calcium supplements and most multivitamins
15 also contain vitamin D. Depending on the age, a daily intake
16 of vitamin D between 400 and 800 international units (IU) may
17 be prescribed.

18 Recommendations can also include the intake of certain
19 medications that positively affect the bone remodeling cycle
20 and are classified as anti-resorptive medications. Anti-
21 resorptive medications slow or stop the bone resorbing portion
22 of the bone-remodeling cycle but do not slow the bone-forming
23 portion of the cycle. As a result, new formation continues at
24 a greater rate than bone resorption, and bone density may
25 increase.

26 Bisphosphonates such as alendronate and risedronate
27 help in preventing bone loss. Alendronate helps in both the
28 prevention and treatment of osteoporosis by reducing bone
29 loss, increasing bone density and lowering the risk of
30 spine, wrist and hip fractures. A daily dosage of 5 mg for
31 prevention and 10 mg for treatment may be prescribed.
32 Risedronate also helps in the prevention and treatment of

1 osteoporosis by slowing bone loss and reducing the risk of
2 spine and non-spine fractures. A daily dosage of
3 risedronate may be 5 mg per day.

4 A naturally occurring hormone calcitonin is involved
5 in calcium regulation and bone metabolism in the body.
6 Calcitonin is known for slowing bone loss and increasing
7 spinal bone density while decreasing the rate of bone
8 fractures. Because calcitonin is a protein, it cannot be
9 taken orally because it would be digested before it could
10 work. A daily dosage of 50-100 IU as an injection or 200 IU
11 as nasal spray may be prescribed.

12 Estrogen replacement therapy (ERT) or hormone
13 replacement therapy (HRT) can also be prescribed for
14 prevention and management of osteoporosis. ERT reduces bone
15 loss, increases bone density, and reduces the risk of hip
16 and spinal fractures. ERT is administered commonly in the
17 form of a pill or skin patch. Raloxifene is another drug
18 that can be administered for the prevention and treatment
19 of osteoporosis.

20 One of ordinary skill in the art would appreciate that
21 various modifications could be made to the above
22 constructions without departing from the scope of the
23 invention. It is intended that all the matter contained in
24 the above description should be interpreted as illustrative
25 and not in a limiting sense. For example, other
26 configurations of bone densitometers, biochemical
27 analyzers, gait analysis apparatus, or prevention therapies
28 could be used while still staying within the scope and
29 intent of the present invention.